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This study was performed to determine whether demand based budget estimating techniques for initial spares could be applied during the early acquisition phases of new weapon systems in place of the more traditional cost factors approach. A demand based approach was developed using the AFLC Logistics Support Cost model and compared to the computational techniques used to develop spares buy quantities in both the initial and replenishment provisioning processes. It was found to be sufficiently representative of these processes to justify its use as a budget estimating tool.

A test case was performed to determine whether the demand based approach could be applied to a weapon system actually in early acquisition. The test showed the approach was executable, provided a reasonable estimate, and offered several significant advantages over current estimating techniques.

This paper describes the study, its results, and the potential uses of the demand based technique.

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DEMAND BASED INITIAL SPARES COST ESTIMATING

IN EARLY ACQUISITION PHASES

FINAL REPORT

NOVEMBER 1990

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ALD/LSS
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EXECUTIVE SUMMARY

This study was performed to determine whether demand based budget estimating techniques for initial spares could be applied during the early acquisition phases of new weapon systems in place of the more traditional parametric (cost factors) approach. After researching existing spares cost models and data sources available during early acquisition, an approach for early initial spares estimating was developed using the AFLC Logistics Support Cost (LSC) model. The approach was compared to the computational techniques used to develop spares buy quantities in both the initial and replenishment provisioning processes and was found to be sufficiently representative of these processes to justify its use as a budget estimating tool.

A test case was performed to determine whether the demand based approach could be applied to a weapon system actually in early acquisition, the Advanced Tactical Fighter. The test showed the approach was executable, provided a reasonable estimate, and offered several significant advantages over current estimating techniques.

In general, the results of the study strongly support the implementation of demand based initial spares estimating during early acquisition. The approach allows for consistent application of the same estimating technique throughout a system's life cycle and encourages standardization of estimating procedures to better facilitate the defense of budget estimates.

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DEMAND BASED INITIAL SPARES COST ESTIMATING IN EARLY ACQUISITION PHASES

FINAL REPORT

1.0 BACKGROUND

The current definition of initial spares includes all recoverable items required as initial stockage at all levels of maintenance and supply, including growth in pipeline requirements to cover the entire production cycle of newly fielded end items. Budget estimates for aircraft initial spares (BP1600) have traditionally been developed by AFLC/MMMR using factors derived from historical data. For example, an initial spares requirement might be estimated as 10% of the flyaway cost for a new system. In developing these budget factors, data from a historical weapon system comparable to the one under development are adjusted at the major subsystem or weapon system level to reflect expert opinion on the new technologies, performance and supportability characteristics, and operating and maintenance concepts of the new system. Despite the adjustments, this estimating technique is very insensitive to the subtle relationships between spares requirements, system performance, and the support environment because of the aggregated level at which it is applied and because the support environment is not explicitly considered. The budget factor technique provides little visibility into the conditions driving the estimate. This makes the initial spares budget estimates difficult to defend at the Air Staff and Congressional levels, particularly in the current fiscally constrained environment.

Unlike the BP1600 estimates, estimates of aircraft initial spares requirements (buy quantities) are demand based. This means they are explicitly computed using the actual characteristics of the weapon system such as component reliabilities, flying hour programs, and basing and maintenance concepts. This demand based approach makes it easier to see the causes driving each requirement and promotes better understanding of the logistics needs.

The ideal scenario would be to develop BP1600 cost estimates using demand based techniques like the ones employed in the initial provisioning process. In fact, for many years, this idea of demand based spares cost estimating has been advocated in studies performed by AFLC/MMI, ALD/LSS and the AFIT School of Systems and Logistics. Unfortunately, from a practical standpoint, the detailed data required to generate the buy quantities for each aircraft component aren't available until late in the acquisition cycle. As a result, initial provisioning quantities can't be used to develop the BP1600 estimates, which are needed even in the earliest acquisition phases. Thus, the factor based approach has prevailed despite the support for demand based estimating in the analysis and academic communities.

2.0 PURPOSE

The purpose of this study was twofold:

(1) To locate or develop a demand based spares cost estimating model that mirrors spares requirement computational

techniques in the provisioning process, and

(2) To determine whether the practice of basing spares budget estimates for new weapon systems on comparable, historical weapon system data could be extended from the factor method to the demand based method in early acquisition phases.

Thus, the intent of the study was to not only formulate a demand based estimating approach but to also apply the approach to a weapon system under development. Such a practical application would establish the feasibility of the technique.

The study was focused on estimating an aircraft initial spares budget during the demonstration/validation (dem/val) phase of system acquisition. The first step taken was to investigate existing demand based cost estimating techniques and select one comparable to the requirements estimating techniques normally employed during the provisioning process. Next, the technique was applied under "real life" conditions using a system currently in dem/val, the Advanced Tactical Fighter (ATF). This step involved identifying a comparable, historical system and determining what ATF-specific data existed during dem/val that could be used to adjust data from the comparable system. This application of the technique and the resulting estimate provided valuable insight into the types of problems, particularly relating to data, that would be encountered when implementing early demand based cost estimating. It also highlighted the advantages to be gained from using the new approach.

3.0 MODELS

A survey of existing spares cost estimation models was conducted to identify one for use in this study. The models studied included the AFLC Logistics Support Cost (LSC) model, the ALD LSC model, the LCCH model, and the AFLC Form 166 spreadsheet program. While the estimating approaches in all the models were very similar, only the AFLC LSC model was considered validated by the AF Cost Center and the Cost Analysis Improvement Group (CAIG) for doing life cycle cost estimates. As a result, it was selected as the primary computational tool to be investigated, and subsequently employed, during this study.

Before the study could proceed using the LSC model, a determination had to be made of the model's comparability with the computational techniques used to determine initial spares requirements. AFLCR 57-27, "Initial Requirements Determination," contains the instructions for the "Recoverable Items Initial Requirements Computation Worksheet" (AFLC Form 614), which is the standard approach for determining buy quantities for initial spares. Additionally, the regulation allows for the use of mathematical models to perform the computations and, in fact, AFLC/MMIE recommends the use of the MOD-METRIC model documented in AFLCP 57-13, "Recoverable Inventory Control using MOD-METRIC." The LSC model was compared to both of these approaches. The results of these comparisons were further compared to the results of a comparability study made between the LSC model and the DO41 system by Management Consulting and Research, Inc. (MCR) in their report "Logistics Support Cost Model Validation" (May 1990.) The DO41 system is used by AFLC to determine replenishment spares rather than initial spares requirements but it computes the replenishment spares quantities

by first computing the initial spares pipelines. Therefore, it seemed appropriate to review the DO41 equations as part of this study, too.

The comparisons indicated that DO41 was the most comprehensive of the computational techniques. This was expected since it is employed late in the acquisition cycle when large amounts of data are available to facilitate detailed computations. The LSC model was not as comprehensive but it did contain the majority of the initial spares elements necessary for determining a reasonable estimate. Additionally, with the exception of safety levels, the DO41, Form 614, MOD-METRIC, and LSC used very similar equations. As a result, it was concluded that the LSC model was sufficiently representative of the other techniques to serve as a budget estimation tool for initial spares. It should be remembered that the intent is to use this tool in early acquisition when highly detailed, fully comprehensive estimates are not possible because of data constraints and uncertainty about the new weapon system's design. Thus, an exact correlation between the LSC model and the other computational techniques isn't required.

Appendix 1 contains further discussion of the comparisons between the four models. It also gives the recommendations for corrections to those areas where the LSC differed significantly from the other techniques. These recommendations were previously made in the MCR report and AFLC/ACCCE has begun to pursue their implementation in the latest versions of the model. The end result will be a markedly improved estimation capability. Because the newer LSC versions were not available during the time frame of this study, an older version was used and supplemental SuperCalc IV spreadsheets were developed to offset several of the existing shortfalls. Appendix 2 describes these spreadsheets.

4.0 CASE STUDY

The idea of using the LSC model for initial spares budget estimates is not a new one. The AFLC/MMIS report, "Analytical Review of Aircraft Initial Spares Budget Estimating Models" made a similar recommendation in Feb 1990 after comparing the LSC and the DO41 system. The recommendation, however, was never implemented. Concerns about the level of effort required to use the model, the availability of data in early acquisition, and the genuine benefits to be derived from employing a demand based approach have hampered its adoption. To address these concerns, a case study was performed on a system in early acquisition. The ATF, which was in dem/val during this study, was chosen as the test case.

4.1 DATA

4.1.1 REQUIREMENTS

To perform the ATF estimate using the LSC sparing algorithm and supplemental spreadsheets, certain data elements were required. For the fleet, data were needed concerning the flying hours per aircraft, the delivery schedule, pipeline times (repair cycles and order and shipping times), and basing concept (overseas versus CONUS). Additionally, the model required information on the specific aircraft components, usually down to the 4- or 5-digit Work Unit Code (WUC)

level. These data requirements included the number of each component installed on the weapon (QPAs), Mean Time Between Demands (MTBDs) for each item, component unit costs, and maintenance data such as Not Repairable This Station (NRTS) and base and depot condemnation rates.

4.1.2 PROBLEMS

In late acquisition, data for demand based models are obtained from contractors, field test agencies, and the using and supporting commands. While the same data sources were researched for the ATF estimate in dem/val, the data were either incomplete, unobtainable, or had not been developed sufficiently to meet the model and spreadsheet requirements. The lack of detailed data on the ATF was the result of three situations inherent in most early acquisition programs: (1) the lack of a clearly defined weapon system which made it almost impossible to obtain "hard" data on component reliabilities and maintenance concepts, (2) the introduction of new technologies about which little was known concerning their logistics characteristics and impacts, and (3) differing approaches by each contractor in the development of the system which resulted in different types of data being available from each contractor at different times (e.g., reliability data were available from contractor "A" but not from contractor "B" while the opposite was true concerning maintenance concept data). While the first two situations cannot be avoided due to the very nature of the dem/val phase, the third could be alleviated in future programs by better specification of data requirements in early acquisition phase contracts. Demand based estimating actually facilitates clearer definition of the data elements needed from the contractors for the SPO to perform their estimates.

4.1.3 DATA COLLECTED

Actual ATF data that were eventually obtained consisted of: (1) preliminary production schedules, flying hour programs, basing concepts, and unit flyaway costs from the ATF System Program Office (SPO) and (2) reliabilities at the 3-digit WUC level from one of the two contractor teams. Additionally, standard factors from AFLCP 173-10, "AFLC Cost and Planning Factors," for repair cycle and order and shipping times were used in the estimate. The remainder of the required data elements (NRTS and condemnation rates, component unit costs, engineering change order factors) could not be obtained for the ATF.

For those parameters that lacked ATF data, a comparable weapon system's data were used to develop input values. The F-16C was used as the comparable weapon system for these purposes even though the SPO has regularly applied the F-15C as its baseline for comparison. This decision was made for several reasons. First, early engineering studies to develop a baseline comparison system for each of the major functional areas on the ATF indicated that the ATF's systems were comparable with those of the F-15C, F-18 and F-16C with the bulk of the systems (64%) being matched to the F-16C. The comparative baseline resulting from these studies is still being used as part of the Logistics Composite Model (LCOM) manpower studies on the ATF. Second, the F-16C was a newer aircraft whose technologies and costs were

probably closer to the ATF's simply by virtue of the age of the system. And finally, the F-16C data for performing the estimate were readily available whereas the F-15C and F-18 data were not easily accessible. Efforts are being made to obtain data for the F-15C and F-18 so an estimate based on the early engineering studies can be performed. (See Section 7.0, "Follow-on Studies.")

Appendix 2 provides an explanation of how ATF values were developed from the F-16C data. The development technique essentially involved allocating ATF system level reliabilities and unit costs across F-16C components based on the contribution each F-16C component made to the overall F-16C system values. Additionally, F-16C maintenance data were changed on the avionics to reflect the ATF's 2-level maintenance concept (organizational and depot) and adjustments were made to account for the ATF's dual engine design. Appendix 3, Attachment 2 contains the ATF data developed for the LSC model.

4.2 ESTIMATE

Once all data files were developed, the LSC model and spreadsheets were run using the ATF flying hours, basing concept, and production schedule. Appendix 3, Table 4, provides the numeric results of the estimate. Like all programs in early acquisition, the ATF experienced numerous changes in program structure and weapon system design. As a result, the estimate had to be baselined using the data, aircraft configuration, and program assumptions in effect at a point in time. The demand based ATF estimate should be considered current only through 1 Jan 90, the close-out date for data collection during this study. Additionally, it should be noted that the estimate does not include whole spare engines, support equipment or training equipment. It does, however, include engine components and engineering change order costs. Furthermore, the SPO initial spares estimate used for comparative purposes in this study encompassed the same cost elements and aircraft systems as the demand based estimate.

The ATF demand based estimate was 6.3% greater than the SPO's Fiscal Year 1989 Annual Estimate developed using parametric techniques. Because the parametric estimate masked the interrelationships between system performance and supportability parameters, it was impossible to precisely identify, or quantify the impact of, each factor contributing to the difference between the estimates. However, the small difference between the estimates was most likely due to the use of the F-16C as baseline for one estimate and the F-15C for the other and to the inherent errors in both estimates resulting from the use of preliminary ATF data.

5.0 ASSESSMENT OF THE DEMAND BASED TECHNIQUE

The results of the case study indicate that demand based estimating can provide a reasonable initial spares estimate even in the data-constrained environment common to programs in early acquisition. Additionally, the application of the approach to the ATF illustrated a number of advantages and disadvantages the demand based technique has in comparison to the parametric method.

The primary disadvantage of the demand based technique is the level of effort required to initially develop the LSC data base for a new

weapon system. The process for doing this includes (1) identifying a comparable weapon system, (2) locating data for that system, and (3) adjusting the data to reflect whatever is known about the actual weapon system under development. The identification of baseline comparison systems is a standard activity within most acquisition programs and has to be done for parametric estimates, too. As a result, obtaining this information shouldn't be difficult for any cost estimator employing the demand based technique. Obtaining detailed data for the comparable system is another matter. The length of time and the level of effort needed to build an LSC data base are entirely dependent on the complexity of the comparable weapon system and the availability and quality of its historical data. The F-16C data base was already available in the correct format before this study began. However, on-going efforts to develop a similar data base for the F-15C indicate it may take 3-4 months to locate, obtain, and format the required component level data. The parametric technique, on the other hand, requires significantly less data at a much higher level (major system or weapon system level) and information at these levels is relatively easy to obtain in comparison to the component level data required for the LSC model. In either case, once the data have been collected, adjusting it to reflect known qualities of the system under development is relatively trivial. It takes a little longer to adjust the data for the demand based approach because the technique models in greater detail and employs more data elements but the adjustment methodologies (see Appendix 2) are essentially the same for both the parametric and the demand driven approaches.

The level of effort disadvantage is by no means insurmountable. Planned upgrades to the LSC input procedures will significantly reduce the time required to initially develop data bases and adjust existing data files. Additionally, efforts are already underway within ALD/LSS to generate a data base library containing LSC files for various weapon systems which can be used to baseline initial spares estimates on future systems. These advances should eliminate most of the difficulties in setting up a demand based initial spares cost estimating program on a new weapon system. However, even without the on-going efforts to minimize problems associated with the demand based technique, the advantages of implementing the approach far outweight the disadvantages.

Principal among the advantages of using demand based costing is that it creates a direct tie between the budget development and provisioning processes as discussed in Section 3.0. Fewer disconnects should arise between spares requirements and budgets because of the application of demand based techniques in both processes. Even though the demand based techniques used in each process differ slightly, they all operate from the same basic mathematical principles and differences between them can be more easily explained than those between the current parametric cost estimates and the demand based spares requirements.

Also, fewer disconnects associated with estimating methodologies will exist between the budget estimates made in different acquisition phases because the same demand based approach can be used throughout a weapon system's life cycle. The ability to consistently apply the same technique across phases will promote more thorough understanding of how the estimates are made, which should, in turn, facilitate better

defense of the estimates in the budgeting process. With parametrics, the estimating technique changes as the acquisition phases and cost estimators change. This lack of continuity is a major weakness of the current approach to budget estimating.

The third significant advantage to the demand based approach is that it explicitly models system performance, the support environment, and the operational concept. By definition, this explicit modeling produces estimates sensitive to changes in these areas. This makes the demand based technique a good tool for performing trade-off studies to assess the cost impacts of reliability and maintainability improvements, changes in the basing scenario (CONUS versus overseas), alternative maintenance concepts (2- versus 3-levels), improvements to Air Force logistics operations which affect repair cycle times, and changes in the production schedule. As an example, Figure 1 shows the changes in F-16C pipeline spares costs when order and shipping times are increased or decreased in one day increments within the LSC model.

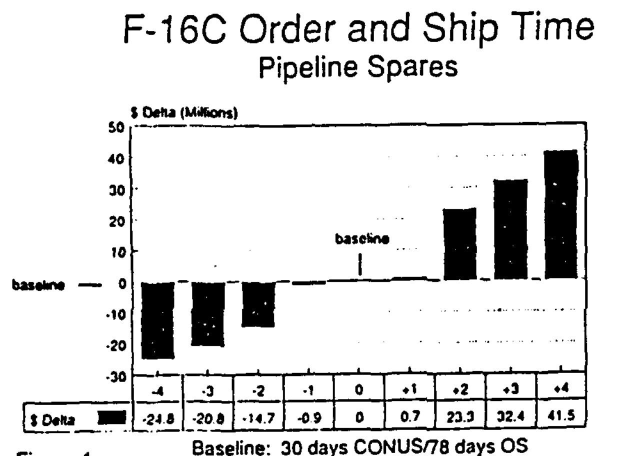

Figure 1

Figure 2 provides another example of a trade-off study. It illustrates the cost impacts of changing the base and depot stock levels for the F-16C to meet various fill rate requirements.

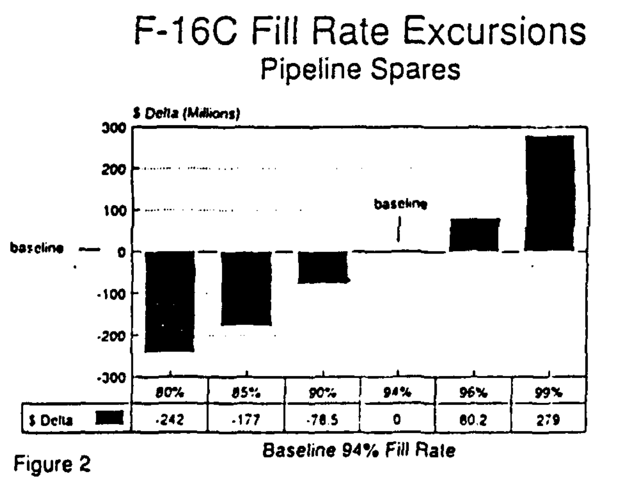

Figure 2

The charts on the preceding page represent only two of the many types of studies that can be performed using the demand based approach, but they are sufficient to show the value of the approach as a program management tool, particularly on older programs undergoing extensive upgrades and modifications. When a parametric approach is used, however, it is significantly more difficult to assess the impacts of programmatic changes because the cost drivers are not explicitly modeled or easily visible. In many instances with this approach, the only means of evaluating the effects of changes would be to adjust the cost factors based on expert opinion supported by little or no quantitative evidence. Such subjectivity severely limits the usefulness of the parametric costing technique as a trade-off tool.

Finally, like most parametric techniques, demand based cost models are usually automated. As a result, estimates can be made quickly and can be easily revised once the initial data files are developed. For example, it takes less than an hour to generate an F-16C LSC estimate even though 736 components, 20 bases and 8 years of production are modeled. Furthermore, planned upgrades to the LSC model, particularly in the area of data entry, will greatly enhance the user-friendliness of the technique and facilitate incremental updating and refinement of cost estimates as more information on the new weapon system becomes available. Essentially, this will allow the estimate to evolve as the weapon system evolves.

6.0 RECOMMENDATIONS

While only time will tell whether the ATF demand based estimate was good, the advantages of consistency of approach, sensitivity, and ease of use strongly support the implementation of demand based initial spares budget estimating during the early acquisition process. Historically, AFLC/MMMR developed the BP1600 estimates but recently, efforts have been undertaken to make initial spares budget development a System Program Manager (SPM) or System Program Office (SPO) responsibility. As such, the SPMs and SPOs would most likely be the employers of the demand based technique. These organizations will also find the technique useful for generating annual estimates, performing trade-off studies, and managing life cycle costs. Additionally, the technique can be used as a tool for source selections, Cost and Operational Effectiveness Analysis (COEAs), and Independent Cost Assessments (ICAs.) In short, the demand based approach will provide valuable support to the decision-making process throughout a weapon system's life.

To implement the approach, a user would need to select a demand based technique early in the program's life cycle (concept exploration or dem/val.) While this study used the AFLC Logistics Support Cost model, other techniques could be used such as the LCCH, ALD LSC, and Cost Analysis Strategic Assessment (CASA) models once they have been validated. While many similarities exist between the various demand based models, they often differ in the details of how they compute estimates and the conditions under which they should be applied. The Air Force Cost Center, the AL organizations within each AFSC product division, and ALD/LSS can provide assistance in selecting the computational tool most appropriate for use with a given weapon system.

Once a computational tool has been chosen, the user would have to

establish a baseline comparison system whose historical data would be used to run the model. This baseline system could consist of an entire weapon system that is comparable to the one under development or it could be a collection of major subsystems from a variety of existing systems which together present a good picture of the capabilities the new weapon will have. The contractors could be required to determine the comparable system and deliver the data base for it or the engineers, logisticians and cost estimators within the user's organization could perform these functions using their own expertise and existing Air Force data bases (D056, D041, etc.) In either case, the specific data requirements will be driven by the model selected for use with the program. Most of the models will require reliability and cost data in some form but the level of detail needed and the requirements for other data elements will be specific to the model being used.

When the baseline comparison system and data base have been developed, the model can be run to generate the baseline estimate. Subsequent estimates will result from updates and adjustments made to the baseline as more information becomes available on the new weapon system. This continuous updating is essential to the effective application of the demand based approach and would be facilitated by specifying, in the Request for Proposal, the model to be used for estimating purposes and by contracting for delivery of data to support the updating and execution of the model.

While the implementation of the technique appears complex, it should be noted that the approach is really just an extension of Logistics Support Analysis (LSA) techniques into the costing arena. Just like LSA, the approach advocates the systematic development of estimates based on extrapolation of historical system performance. It is a positive step toward standardizing the tasks to be accomplished in all acquisition programs and should be encouraged.

7.0 FURTHER STUDY EFFORTS

Considerable work remains to be done in the area of demand based estimating in early acquisition. Below are summaries of current related activities and recommendations for further studies.

(1) Additional efforts are underway to further validate the results of this study and still more are needed. The first project is to regenerate the ATF demand based estimate using the F-15C as a baseline comparison system (like the ATF SPO does) and using the mixed system (F-15C, F-16C, F-18) baseline from the early ATF engineering studies. The second project involves locating historical BP1600 estimates and actual initial spares expenditures for the F-16C and F-15C and comparing them to the LSC model outputs. Finally, other case studies need to be performed for weapon systems other than fighters.

(2) Several projects have been undertaken to reduce the workload associated with implementing the demand based approach. The first involves upgrades to the LSC model. At this time, AFLC/ACCCE, in conjunction with MCR, is pursuing this. These upgrades should improve input procedures, expand the model's capabilities, bring the LSC's equations more in line with those in the D041 system, and handle stock funding of repairable items. The second project is aimed at creating

an ALD/LSS library of LSC data bases for historical systems. Easier accessibility to data should reduce the time needed to initially set up the model for a new program.

(3) Initial spares were the focus of this study but more in-depth research is needed on other categories of spares such as condemnation/replenishment spares, War Readiness Spares Kits (WRSK), repair materiel, and support and training equipment spares. A 1989 study by AFLC/MMIS of the spares estimating factors in AFLCR 67-7, "Stock Fund Initial Spares Requirements," recommended the development of demand based repair materiel estimates. The status of this effort is not known. For the other spares categories, it is not known whether efforts have been made to develop new estimating techniques for use in early acquisition phases.

(4) While the LSC model was used for this study, other models for early spares estimating need to be investigated. Candidates for study include the LCCH, the ALD LSC, and the CASA models. Most of these cost models still require validation and verification in order to be used for CAIG reports.

(5) The models mentioned above, including the LSC model, estimate other life cycle cost elements besides spares (e.g., depot repair costs, second destination transportation costs.) Most of these elements are also parametrically estimated during early acquisition. The potential exists to apply the approach advocated in this study to estimate these other cost elements and perhaps even overall weapon system life cycle cost early in programs. More research is needed into the unique problems of early demand based estimation of each cost element.

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(2) AFLCR 57-4, "Recoverable Consumption Item Requirements System (D041)"

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(11) "Development of Standard Spares Projection Factors," HQ AFLC/MMIS, Jun 1989

(12) "Initial Spares Project Final Documentation," ALD/LSS, May 1988

(13) "ALD Logistics Support Cost Model User's Handbook,Version 1.1," ALD/LSS, Jan 1979

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APPENDICES

Appendices 1 and 2 along with the main report provide sufficient information and guidance for interested analysts and cost estimators to implement the demand based cost estimating approach on their programs. However, Appendix 3, which provides the details of the Advanced Tactical Fighter case study, is competition sensitive and can not be included as part of the report sent to most addressees.

Comments on the study, questions about the results, and suggestions for further research are welcomed.

APPENDIX 1

COMPARISON OF INITIAL SPARES COST AND REQUIREMENTS MODELS

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APPENDIX 1

COMPARISON OF INITIAL SPARES COST AND REQUIREMENTS MODELS

1.0 INTRODUCTION

This appendix describes the comparison made between the AFLC Logistics Support Cost (LSC) model, the AFLC Form 614, the MOD-METRIC model and the DO41 spares equations. As previously mentioned in Section 3.0 of the main report, Form 614, MOD-METRIC and DO41 represent the initial and replenishment spares requirements determination approaches employed by AFLC and, therefore, serve as the basis for assessing the acceptability of the AFLC LSC model as a tool for estimating initial spares budgets.

The intent of the appendix is to present an assessment of the comprehensiveness of each model in computing initial spares. As a result, the discussion will be general in nature and will center around the various initial spares categories computed by each model. While not all inclusive, the eight categories investigated represent the bulk of the initial spares requirements.

Specifics concerning the computational techniques employed in the models will be covered on a "by-exception" basis only and no numeric results of the comparison will be presented even though computations were made with each of the models as part of the overall study. The reader is referred to the bibliography for documentation on the equations used by each estimating technique and to the MCR report, in particular, for a thorough comparison of the LSC and DO41 equations.

2.0 COMPARISON

Table 1 on the next page presents a matrix of eight initial spares categories computed by the various models. In the sections following the table, each spares category will be discussed along with the similarities and differences between how each model estimates the category. As previously mentioned, the comparisons will be general in nature looking at the computational approach overall rather than at the specific equations.

TABLE 1

SPARES ELEMENT	DO41	FORM 614	MOD-METRIC	LSC
1. Organizational and Intermediate Maintenance (OIM) Base Order and Shipping Time	YES	PARTIAL	PARTIAL	PARTIAL
2. OIM Base Repair Cycle	YES	YES	YES	YES
3. OIM Base Safety Level	YES	NO	PARTIAL	PARTIAL
4. Depot Repair Cycle	YES	YES	YES	YES
5. Job Routed (JR)/Non-JR Depot Repair Cycle and Depot Overhaul Stock	YES	YES	NO	NO
6. Depot Safety Level	YES	NO	YES	NO
7. Additive Requirements	YES	YES	NO	NO
8. Procurement Leadtime	YES	YES	YES	YES

* YES - Fully computes requirement
PARTIAL - Partially computes requirement
NO - Does not compute requirement

2.1 BASE LEVEL SPARES

2.1.1 ORDER AND SHIPPING TIME (OST) PIPELINE

The OST pipeline covers the time to order and ship spares to the base from the depot whenever components are sent to the depot for repair or are condemned at the base. It is based on the average shipping and handling times and average supply demand rates at the base level. DO41 is the only one of the four models to fully compute this requirement. The other three models used essentially the same equation as DO41 but failed to include the spares condemned at base level in the computations. MCR recommended inclusion of these spares in the new version of the LSC model. For the purposes of this study, they were computed in a supplemental spreadsheet once it was determined they accounted for a significant error in the results.

2.1.2 BASE REPAIR CYCLE TIME (BRCT) PIPELINE

The BRCT pipeline represents the average number of spares resident in the base level repair process at any given point in time. All four models used basically the same computational approach.

2.1.3 SAFETY LEVEL

The function of the base safety level is to provide for fluctuations in the average spares requirements computed for the base level OST and BRCT pipelines previously discussed. Only the DO41 fully computed this requirement since it was the only model to fully compute both of the base level pipelines. DO41 uses the Aircraft Availability Model (AAM) to determine this requirement. This program employs a marginal analysis technique to minimize the spares costs subject to a weapon system availability constraint. MOD-METRIC also employs a marginal analysis algorithm to compute its base safety level. As mentioned above, however, the base condemnations are not included in this computation.

The LSC model, like the MOD-METRIC, does not include base condemnations in its safety level computation. It differs further from the DO41 by computing its safety level using a closed form equation which is based on the Normal approximation to the Poisson distribution. This equation gives significantly different safety levels from the marginal analysis technique. MCR recommended modifications to this equation for small pipelines and these are being worked in the new versions of the model. Additionally, incorporation of a marginal analysis algorithm into the LSC is being considered. For this study, the equation was used without modification. However, it was applied not only to the base pipelines computed within the model but also to the base condemnation pipeline generated in the supplemental spreadsheets.

2.2 DEPOT LEVEL SPARES

2.2.1 DEPOT REPAIR CYCLE TIME (DRCT) PIPELINE

The DRCT pipeline addresses the average number of spares in the depot level repair process which were originally generated at the base level. All four models used very similar equations to compute this requirement.

2.2.2 JOB ROUTED (JR)/NON-JR REPAIR CYCLE TIME PIPELINE AND DEPOT OVERHAUL STOCK

The JR/NJR pipeline and depot overhaul stock cover spares associated with programmed depot maintenance and component overhaul. The LSC and MOD-METRIC models do not address these areas. MCR recommended their incorporation into the LSC but to date no effort has been made to do so. No recommendation has been made for their incorporation into MOD-METRIC even though it is routinely used to determine initial provisioning buy quantities. One of the primary reasons for this is the lack of quantitative information needed to determine these quantities early in a program's life. Frequently these data are not available until several years after the system is fielded so few spares in these categories are purchased during the initial provisioning process. In light of this, no effort was made to compute this requirement during this study and it was not considered a significant enough difference to disqualify the LSC model as an initial spares budgeting tool. It's inclusion in the new versions of the LSC,

however, will bring the model more in line with DO41. This should be encouraged.

2.2.3 SAFETY LEVEL

The DO41 and MOD-METRIC depot safety levels are computed with the same marginal analysis techniques used for their base safety levels. The version of the LSC model used during this study, though, did not compute depot safety stock. The newer versions of the model, however, include depot safety stock. To account for this during the study, a supplemental spreadsheet was developed to compute the requirement. The same closed form equation used for the LSC base level safety stock was employed in the spreadsheet. Consideration is also being given to upgrading this section of the model with a marginal analysis algorithm.

2.3 OTHER SPARES

2.3.1 ADDITIVE REQUIREMENTS AND SPECIAL LEVELS

These requirements address negotiated base stocks, foreign military sales, depot floating stock and war readiness materiel. They are not included in the LSC and MCR recommended they not be added to the model because they represent special requirements that must be tracked separately. No effort was made to include these requirements in this study.

2.3.2 PROCUREMENT LEAD-TIME

Procurement lead-time spares are purchased to ensure adequate stock during the administrative and production lead-times for items. DO41 does not compute and report this spares element separately as the other models do; however, the computations are inherent in the replenishment spares calculations performed by the model. All four models employ essentially the same computational approach with variations occurring primarily in the range of values accepted as lead-times.

2.4 ADDITIONAL CONSIDERATIONS

Table 1 does not portray several areas that need to be discussed when comparing the LSC to the other three models. First is the level at which items are modeled. DO41 and Form 614 lend themselves to use with items at the component/piece-part level whereas MOD-METRIC and LSC function best at the line replaceable and shop replaceable unit levels. To offset this lack of detail, the LSC model, unlike the others, includes a factor to account for shop replaceable units when data are not available on them. This should provide for a better estimate than would be possible if the LSC were used without the factors. These factors, however, need further study to ensure their accuracy.

The second area that needs to be covered is the inclusion of engineering change order costs in the LSC model. These are not explicitly considered in the other models; however, since DO41 and Form 614 are usually executed at the component/piece-part level, changes to these systems are reflected on more of a real time basis.

This would usually cover the effects of engineering change orders on the systems. ECOs are often considered in the development of program office annual estimates so this cost element was retained in the estimate made during this study.

The only other differences in the computational approaches between the models relate to internal program organization. For example, different rounding algorithms were employed, acceptable ranges for input parameters varied, flying hour programs and basing concepts differed in relation to whether the model reflected a build-up scenario or a steady-state environment, and the units in which the data elements were expressed (days versus months, etc.) differed. These types of differences are to be expected given the various purposes for which the models were created.

3.0 CONCLUSIONS

Despite the differences between the LSC model and the requirements determination models, sufficient similarity exists between them to justify using the LSC as a budgeting tool for initial spares. The upgrades already in progress will make the new versions of the model even more representative of the provisioning models and will further promote the use of demand based estimation for budgeting purposes.

APPENDIX 2

COMPUTATIONAL METHODS

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APPENDIX 2
COMPUTATIONAL METHODS

1.0 INTRODUCTION

This appendix provides information on the computational techniques used to perform the parametric and demand based estimates of initial spares discussed in the main report. The description of the parametric technique focuses on the methodology used by the Advanced Tactical Fighter (ATF) System Program Office (SPO) to develop the annual estimate used for comparative purposes in the case study. The discussion of the demand based approach outlines the model and spreadsheets used to generate the ATF demand based estimate.

2.0 PARAMETRIC TECHNIQUE

Parametric estimates have been used in the past primarily because of their simplicity and the minimal amount of data required to perform them. They can be generated quickly using readily available Air Force approved factors and the computations are relatively easy to understand. Despite this, they do have a number of disadvantages which limit their usefulness. Primary among these is the high level at which parametrics operate. Assumptions, adjustments and computations are all made at the major subsystem or weapon system level. Because system design, maintenance and operating concepts, and the Air Force logistics structure are not completely addressed at this high level, the impact of changes in these areas cannot be easily quantified. As a result, cost estimators using these techniques are forced to make subjective adjustments which are difficult to defend in the budgeting process. The following description of the parametric technique used by the ATF SPO serves to illustrate this disadvantage.

Historically in early acquisition, initial spares costs have been estimated by applying a factor to the flyaway cost of the weapon systems delivered in each fiscal year. For the Fiscal Year 1989 ATF Annual Estimate, these factors were developed by the SPO's Directorate of Program Control in conjunction with AFLC/MMMR. Using the F-15C as a baseline comparison system, the SPO computed the ratio of initial spares costs to flyaway costs from historical F-15C data for the airframe, engines and avionics. These ratios were then adjusted to reflect the expected differences in reliability between the F-15C and ATF. Further adjustments were made subjectively to account for warranties, engineering change orders and recent changes in the definition of initial spares which will affect the ATF. These adjusted ratios were used as the initial spares estimating factors and were applied to the total flyaway cost for aircraft delivered in each fiscal year to obtain the initial spares costs for that year.

3.0 DEMAND BASED TECHNIQUE

3.1 MODEL

As mentioned in Section 3.0 of the main report, the AFLC Logistics Support Cost (LSC) model was chosen as the basis for most computations

made in the initial spares demand based estimate. Rather than duplicate the equations used in the LSC model here, the reader is referred to the users' documentation which can be obtained from AFLC/ACCCE, WPAFB, OH 45433-5000.

Appendix 1 noted several shortcomings in the version of the LSC model available during this study and the MCR report, "Logistics Support Cost Model Validation," further explains these. The more significant of the equations omitted from the LSC were computed separately using supplemental SuperCalc IV spreadsheets developed in ALD/LSS. The following section details these computations.

Upgrades to the LSC to include the missing equations were in progress throughout this study and a new version of the model should be available in the near future. These upgrades to the model should eliminate the need to perform part of the estimate external to the model and prevent some of the inaccuracies due to computing separate safety levels and to rounding separately in the spreadsheet and the model as shown in the equations below.

3.2 SPREADSHEET EQUATIONS

The following supplemental initial spares computations were made using SuperCalc IV spreadsheets. They were performed on each component modeled on the aircraft.

a. The order and shipping time pipeline for items condemned at the base and the safety stock for this pipeline were not included in the LSC model. The pipeline equation was

$$\text{ASPARES(i)} = \frac{\text{DEMANDS(i)} * \text{OST(i)} * \text{BCOND}}{\text{NOBASES(i)}}$$

where

i = Index representing a particular production year

DEMANDS = Mean demands for an item generated per month in year i

$$= \frac{\text{PKFFHS(i)} * \text{QPA} * \text{UF}}{(\text{MTBD/ADJ})}$$

PKFFHS = Peak monthly fleet flying hours in year i

QPA = Quantity of the item on each aircraft

UF = Utilization factor

= The ratio of operating hours to flying hours

= 1 for this study

MTBD = Mean time between demands

ADJ = Adjustment factor for reliability growth

= 1 for this study

OST = Average order and shipping time for year i

= [OSTCON * (1-PCTOS(i))] + [OSTOS * PCTOS(i)]

OSTCON = CONUS order and shipping time in months

PCTOS = Fraction of total fleet overseas in year i

OSTOS = Overseas order and shipping time in months

BCOND = Base condemnation fraction

NOBASES = Number of bases operating in year i

The safety stock for ASPARES(i) was computed using the LSC model's

safety stock formula. This equation is based on the Normal approximation to the Poisson. The formula used was:

$$\text{ASAFETY}(i) = \text{FMOD} * \text{Sqrt}[\text{ASPARES}(i)]$$

where

FMOD = A value dependent on the fill rate desired for the base and depot
= 1.55 for this study based on a 94% fill rate (LSC default value)

Sqrt = The square root function

The cost in year i for initial spares of type (a) was

$$\text{ACOST}(i) = (\text{Round}[\text{ASPARES}(i) + \text{ASAFETY}(i)] * \text{NOBASES}) * \text{UC} * \text{SRUFACT}$$

where

Round = Function that rounds values up to the next highest integer

UC = Unit cost for the component under study

In the equation above, SRUFACT serves as an adjustment to account for spares of lower level subindentured items (shop replaceable units, SRUs) within the component under study. Only those items modeled as line replaceable units (LRUs) without any information about their subcomponents had the SRUFACT applied to them. These items were characterized in the data files with an SRUIND value equal to 1. The SRUFACT values are contained in the LSC users' documentation.

The value ACOST(i) was further adjusted to reflect the LSC model's engineering change order algorithm so that the total cost for initial spares type (a) was

$$\text{ATOT}(i) = \text{ACOST}(i) + \left(\text{ECO}(i) * \sum_{j=1}^{i} \text{ACOST}(j) \right)$$

where

ECO = Engineering change order factor for year i

The value for ATOT(i) was added to the LSC output in each year as part of the total initial spares estimate.

b. The depot repair cycle time pipeline for items repaired at the depot was computed within the LSC model. However, no safety stock for this pipeline was included. BSAFETY(i) was computed using the same

formula given above with the pipeline value from the LSC represented by

BSPARES(i) = DEMANDS(i) * NRTS * DRCT * (1 - DCOND)

where

NRTS = Not repairable this station fraction
DRCT = Depot repair cycle time in months
DCOND = Fraction of depot returns condemned

The total safety stock cost for initial spares type (b) was

BCOST = Round[BSAFETY(i)] * UC * SRUFACT

This was further adjusted for ECOs as shown above in para. 3.2.a before being added to the LSC output for initial spares.

c. The reprocurement time pipeline was underestimated by the LSC model because SRUs were not considered. For this study, the reprocurement lead-time was taken to be 24 months for each of the first two years of production. The reprocurement pipeline costs from the LSC output were <u>increased</u> by the value

CCOST(i) = CSPARES(i) * UC * (SRUFACT - 1)

where

CSPARES(i) = 1 year of condemnation spares
= 12*DEMANDS(i)*NOBASES(i)* (BCOND+(NRTS*DCOND))

The results of this computation were added to the year 1 and year 2 LSC initial spares output results.

3.3 DATA DEVELOPMENT TECHNIQUE

The basic computational approach taken in the ATF case study was to perform a detailed estimate on a weapon system comparable to the ATF with adjustments made to the comparable system's data in order to more accurately reflect ATF parameters. As previously discussed in Section 4.1.3 of the main report, this approach had to be taken because ATF data were not available in the form and to the level of detail needed for the LSC model and the supplemental spreadsheets.

The F-16C was used as the comparable system and six input parameters for the ATF were developed from its data:

(1) Base condemnation (BCOND) rates - F-16C rates were used in the estimate without any alterations because no information was available on ATF rates during this study.

(2) Not repairable this station (NRTS) rates - Except on avionics components, F-16C rates were used without adjustment. On avionics components, the NRTS rates were set equal to (1 - BCOND) because of the ATF's 2-level maintenance concept (organizational and depot.)

(3) Depot condemnation (DCOND) rates - For non-avionics items, the F-16C DCOND rates were applied directly. For the avionics components, the DCOND rates were adjusted so that the total condemnation rate for an item, with its new NRTS rate, was equal to the total condemnation rate for the F-16C comparable item. For example, if an F-16C avionics component had BCOND = .05, NRTS = .34, DCOND = .12 and total condemnation rate = BCOND + (NRTS * DCOND) = .0908 then the adjusted ATF avionics component would have BCOND = .05, NRTS = .95, DCOND = .043 and total condemnation rate = .0908. The intent of this adjustment was to ensure that the overall ATF condemnation rate, in the absence of any "hard" data, remained the same as the overall F-16C condemnation rate.

(4) Mean Time Between Demands (MTBD) - The technique employed to develop the ATF component MTBDs consisted of allocating high level ATF system reliabilities across the low level F-16C components. The equation used was:

$$MTBD(ATFc) = \frac{MTBD(ATF) * MTBD(F16c)}{MTBD(F16)}$$

where

MTBD(ATFc) = ATF 5-digit Work Unit Code (WUC) reliability
MTBD(ATF) = ATF 2-digit WUC reliability
MTBD(F16c) = F-16C 5-digit WUC reliability
MTBD(F16) = F-16C 2-digit WUC reliability

To illustrate how the equation works, if an F-16C component accounted for 30% of the F-16C airframe's supply demands then, using the formula, the component's adjusted MTBD accounted for 30% of the ATF airframe's supply demands.

EXAMPLE
(numbers are not actual values for any F-16C or ATF hardware)

	MTBD	DEMANDS PER 1000 FLYING HRS.
F-16C Airframe MTBD(F16)	10	100
F-16C Component (30% of airframe) MTBD(F16c)	33	30
ATF Airframe MTBD(ATF)	100	10
ATF Component (30% of airframe) MTBD(ATFc)	333	3

(5) Unit Cost - The unit flyaway cost for the ATF was allocated across the F-16C components in a similar fashion to the MTBDs:

$$UC(ATFc) = UC(ATF) * \frac{UC(F16c)}{UC(F16)}$$

where

UC(ATFc) = ATF 5-digit WUC unit cost
UC(ATF) = ATF unit flyaway cost
UC(F16c) = F-16C 5-digit WUC unit cost
UC(F16) = Aggregate of F-16C component unit costs

The ratio for allocation in this case was the F-16C component cost to the F-16C unit cost. To illustrate, if 2% of the F-16C unit cost was attributed to a particular F-16C component then that component also accounted for 2% of the ATF flyaway cost.

(6) Engineering Change Order (ECO) factors - The F-16C ECO factors were used in the ATF estimate without alteration during the early ATF production years. Because the ATF's production cycle extended beyond the eight year cycle modeled for the F-16C, an average of the F-16C's ECO factors was used for the later years in the ATF program.

Appendix 3 and its second attachment, in particular, contain the results of the foregoing data development process for the ATF. Once these data were developed, they were used in the LSC data files and the supplemental spreadsheets to generate the ATF demand based initial spares estimate.